Well integrity of Fiberglass Casings in Geothermal Well Designs

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22 April 2022

Abstract

Two of the key challenges currently encountered in operating geothermal wells using conventional steel casings are corrosion and scaling. These problems significantly reduce the lifespan of the steel casing systems, causing wellbore integrity issues, which could lead to major environmental contamination. Moreover, the corrosion leads to surface degradation of the casing, causing excessive pressure losses. To prevent major damage, costly workover operations are inevitable, becoming a substantial financial burden and may ultimately jeopardize project economics of steel based geothermal well designs.

Dynaflow Research Group (DRG) is partner in the GEOTHERMICA-funded GRE-GEO project, a multinational consortium of geothermal experts to solve these challenges through development of the new glass fiber reinforced epoxy (fiberglass) casing system for geothermal applications. This paper covers a short overview of a number of studies that were carried out by DRG as part of the GRE-GEO project to investigate well integrity topics like electro static discharge (ESD), wear (erosion and abrasion) and chemical compatibility of the casing material with well fluids. A HAZID study has been carried out to identify potential risks associated with the application of fiberglass in geothermal wells and to offer mitigating actions to manage these risks.

Keywords: geothermal well design, well integrity study, Well Integrity Management System (WIMS), wear, corrosion, chemical compatibility, Electro Static Discharge (ESD), Fiberglass, GRE, glass reinforced epoxy, industry standard, HAZID.

1. HAZID study

It is advised and often required to conduct a hazard identification and associated risk assessment as part of the general management control system (Well Integrity Management System WIMS).

HAZOP, HAZID or BOWTIE methodologies are usually applied to identify these risks and define risk-mitigation measures for each lifecycle of a geothermal well. Although the preparation of such a management control system and associated HAZID studies are the responsibility of the operator it is believed that it is GRE-GEO's responsibility to provide guidance to support the operators with their preparation of the HAZID study and more specifically risks associated with the application of GRE casings in geothermal wells.

In the GRE-GEO project, the HAZID study was initiated at an early stage of the project to support the preparation and selection of the qualification tests required for the materials qualification test program [1]. Also, for the installation tools used during installation the HAZID is a valuable tool to identify GRE specific risks during handling by installation tools that are typically designed for handling of steel casings. HAZID studies for steel-casing based designs that were carried out in the past and that were available in the open literature domain has been used as the basis for the GRE-GEO HAZID study and extended with GRE specific risks. Existing studies often are primarily focused on the installation- and operation phase of the geothermal well lifecycle. Abandoning related risks should also be part of Well Integrity Management System. GRE-GEO has included this phase in the HAZID study as well.

Consequence						*Increasing Probability*				
Severity	**People**	**Environment**	**Assets**	**Reputation**	**Social**	**A**	**B**	**C**	**D**	**E**
						10^{-6} to 10^{-4} occurrence/year	10^{-4} to 10^{-3} occurrence/year	10^{-3} to 10^{-1} occurrence/year	10^{-1} to 1 occurrence/year	>1 occurrence/year
						Rare occurrence	Unlikely occurrence	Credible occurrence	Probable occurance	Likely occurrence
						Never heard of in the global industry	Heard of in the Global industry	Incident has occurred in company	Happens several times per year in company	Happens several times per year in company
1	No/negligible health effect/injury	No effect	No damage	No impact	No impact					
2	Minor/Slight health effect/injury	Slight effect	Slight damage	Slight impact	Local impact	**Manage for continuous improvement**				
3	Major health effect/injury	Localized damage	Localized damage	Considerable impact	Regional impact			**Incorporate risk reduction measures**		
4	Permanent disability / up to 3 fatalities	Major effect	Major damage	National impact	National impact				**Intolerable**	
5	More than 3 fatalities	Massive effect	Extensive damage	International impact	International impact					

Figure 1: HAZID Risk Matrix used in the HAZID study

Besides the role of the HAZID study in the selection of the required materials qualification test and development of installation tools it also provides guidance in the guidelines and the development of the industry standard for GRE casings which is one of the main objectives of the GRE-GEO project.

It should be mentioned that the GRE-GEO HAZID study is focused on GRE material specific topics only but still provides valuable information for the operator in preparation of the WIMS for GRE based casing designs.

1.1. Compatibility of GRE with geothermal well fluids

Below several examples are provided that were investigated as part of the compatibility studies currently carried out by the GRE-GEO consortium.

Corrosion

One of the main reasons to select GRE for geothermal well casings is the excellent corrosion resistance compared to conventional steel casing. The Dutch State Supervision of Mines (SodM) carried out a study [2] into the integrity of 38 geothermal wells owned by 12 different companies. Of these 38 wells (of which 8 wells of recent date), 6 wells showed significant wall thickness reduction in the range from 28% to 85%. 15 wells showed a wall thickness reduction of around 25% and 3 wells were found to leak and were closed in. The conclusion of the study was that the anticipated design lifetime of steel-casing based designs cannot be reached and that the probability of leakage was also significantly increased over time [3]. GRE is therefore seen as an attractive alternative to counter corrosion problems related to high salinity production fluids in geothermal wells [3].

ElectroStatic Discharge (ESD)

From the HAZID study, ESD has been flagged as a potential risk as discharge can form an ignition source in the explosion area of the well. Four areas of concern were raised where ESD could form a potential risk:

1. Pumping of drilling fluids during drilling (electrostatic charge generated by fluid flow along the internal and/or external GRE string/casing pipe wall). Both for the producing and for the injector well.

2. Pumping of cement slurry during cementing operation (flow along the internal and/or external GRE string/casing pipe wall). Both for the producing and for the injector well.

3. Flow of production fluids during operation in both the producer well and injection well (Electrostatic charge generated by production fluid flow along the internal GRE pipe wall)

4. Handling of GRE pipe during installation.

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Analysis electrostatic charge
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Schön's law:
I = 4.v^2.d^2.(1-exp(-L/v.tau))
I = rho.PI/4*d^2.v
rho = 16/PI.v(1-exp(-L/v.tau))

Input variables
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Conductivity WBM          [pS/m] : 3.85e+11
Flow                      [m3/s] : 0.066667
diameter         pipe        [m] : 0.304800
Velocity Q/A               [m/s] : 1.105616
permittivity vacuum       [pF/m] : 8.854000
relative permittivity WBM [pF/m] : 2.000000
Relaxation time              [s] : 4.59948e-11
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Figure 2: Typical input parameters for Elecro Static Discharge (ESD) modelling for fiberglass pipe

An extensive study has been conducted to explore the potential ESD risks identified above [4]. Mitigation actions to minimize the risks were defined and will be part of the guidelines as prepared by the GRE-GEO consortium.

Figure 3: Typical geothermal well – well head

The main findings of the ESD study are:

- **Drilling operations:** OBM or WBM based drilling fluids were found to be highly conductive and show relaxation times in the order of magnitude of picoseconds. This means that accumulated charge in the liquid almost instantaneously dissipates and therefore will not form an ESD risk. Although not necessary earthing via the drill-shaft would contribute to dissipation of charge.
- **Cementing operations:** The same holds for cementing operations. Also cements have a high conductivity and accumulated charge will dissipate almost instantaneously.
- **Production:** Production fluids in general are also highly conductive fluids (high salinity) and thus have very short relaxation times as well and charge will not accumulate in these fluids. In addition, in combination with downstream earthed conductors (valves etc) accumulated charge would dissipate via these conductors to earth.
- **Verify conductivity of fluids used during installation, cementing and production:** As indicated above, typical OBM, WBM, cement slurries and production fluids have a very high conductivity and will not accumulate electrostatic charge in the fluids. It is however recommended to verify the conductivity of the fluids used throughout the lifecycle of the well.
- **Handling of GRE during installation:** The handling of GRE in the explosion area seems to be a potential risk for ESD. Although these risks are equal to ESD risks created by human bodies, precautions will be required to fulfill the requirements provided by industry standards. Examples are e.g. anti-static coatings/sprays, conductive additives to be added to the resin, relative humidity control at the work area or ionizing the air at the working area.

Chemical Compatibility with geothermal fluids

Throughout the lifecycle of the well, casings will be exposed to:

1. Production water
2. Well intervention fluids (descaling chemicals like HCl, HF)
3. Sulfide Reducing Bacteria (SRB)
4. Associated gasses like CO_2, H_2S.
5. Exposure to radioisotopes that are present in the production fluids

An extensive literature study has been carried out to investigate the compatibility of GRE with these fluids [5]. Based on long-term experience with GRE being used in several industry applications it can be concluded that in general the chemical compatibility of GRE is good and limitations in terms of exposure concentrations, -temperatures and -times are well defined.

Based on this information guidelines will be determined for safe operation of GRE casings in geothermal wells. Where needed exposure testing will be part of the test program.

1.2. Wear

Similar as for steel-casings, wear of GRE by for example abrasion during installation and intervention tools (e.g. drill shaft contact or wire line operations) has been identified as a potential mechanism that may affect the well integrity [6]. Wear testing will be part of the GRE-GEO test qualification program.

1.3. Fiberglass based well design - Industry standard

The fiberglass based well design and required testing program to construct a design envelope are also part of the GRE-GEO project. One of the main deliverables of the GRE-GEO project is also the development of an industry standard. These topics are currently in progress. It is the intention to apply the developed fiberglass system in a demonstration well at the end of the project.

2. Conclusions

Several studies related to chemical compatibility, Electro Static Discharge and wear have been carried out to explore the well integrity of geothermal wells in which conventional steel casings are replaced by corrosion resistant fiberglass casings.

A HAZID study has been used as a tool to identify potential risks of using fiberglass casings in geothermal well designs and to support the GRE-GEO team in explore mitigating actions and define/prioritize the test program. The program is currently running as part of the GRE-GEO project.

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